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Effect of irrigation, sulphur and seed inoculation on growth, yield and sulphur uptake of chickpea (*Cicer arietinum*) under late-sown conditions

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ABSTRACT

A field experiment was conducted during the winter seasons (*rabi*) of 2000–2001 and 2001–2002 on sandy-loam soils at CCS Haryana Agricultural Univesity, Hisar, to study the effect of irrigation, sulphur and seed inoculation levels of growth, nodulation and yield of chickpea or gram (*Cicer arietinum* L.) variety 'HC 1' under late-sown conditions. Two irrigations at pre-flowering and pod-development stages gave 16.4 and 7.4% more seed yield over no irrigation and 1 irrigation given at pre-flowering stage respectively. Highest consumptive use of water was recorded with 2 irrigations, while maximum water-use efficiency (WUE) in the control. Application of 40 kg S/ha resulted in better growth, yield attributes, yield, consumptive use, WUE and S uptake than no sulphur and 20 kg S/ha. Inoculation with *Rhizobium* + phosphate-solubilizing bacteria (PSB) significantly increased plant height, dry matter, nodulation, pods/plant, yield, consumptive use, WUE and S uptake over single inoculation of *Rhizobium* or PSB and no inoculation; however, single inoculation with *Rhizobium* or PSB being at par were significantly superior over the control

Key words : Chickpea, Irrigation, Sulphur, *Rhizobium,* PSB, WUE

Farmers are sowing chickpea or gram crop under late conditions after the harvest of cotton and even in December wherever irrigation facilities are available. Under late-sown conditions, application of irrigation to the crop is reported to be beneficial (Dumbre and Deshmukh, 1983). Continuous use of S-free fertilizers, intensification of agriculture with high-yielding crop varieties and use of scarce amount of organics resulted in S-deficiency in crops. Sulphur plays an important role in the formation of S-containing essential amino acids (cysteine, methionine and cystine), synthesis of proteins and promotion of nodulation. Since chemical fertilizers are not only in short supply but also expensive, there is need to supplement these with organic sources more particularly biofertilizers of microbial origin which are cheaper, pollution free and renewable (Mukherjee and Rai, 2000). Since information on the performance of chickpea in respect of optimum irrigation and sulphur levels with suitable seed inoculants under late-sown conditions is meagre, the present investigation was undertaken.

MATERIALS AND METHODS

The field experiment was conducted during the winter (*rabi*) seasons of 2000–2001 and 2001–2002 at the Agronomy Research Farm of CCS Haryana Agricultural University, Hisar (India). The soil was sandy loam; low in organic carbon (0.34%), nitrogen (197.5 kg N/ha) and sulphur (9.4 ppm); medium in phosphorus (17.8 kg P_2O_5/ha); high in potassium (369.5 kg K_2O/ha) and slightly alkaline in reaction (pH 7.7). The experiment was laid out in split-plot design with 3 replications. The treatments consisted of 3 irrigation levels, viz. no post-sowing irrigation (I_0), 1 irrigation at pre-flowering stage (I_1), and 2 irrigations at pre-flowering and pod-development stage (I_2), and 3 sulphur levels, viz. control (S_0), 20 kg S/ha (S_1) and 40 kg S/ha (S_2) in main plots, while 4 seed inoculation levels, viz. no inoculation (B_0), seed inoculation with *Rhizobium* (B_1), seed inoculation with phosphate solubilizing bacteria (PSB) (B_2) and seed inoculation with *Rhizobium* + PSB (B_3) in subplots. Chickpea variety 'HC 1' was sown on 7 December 2000 and 3 December 2001 at rows 30 cm apart by *kera* method using seed @ 50 kg/ha and harvested on 24 April 2001 and 21 April 2002. A measured quantity of 60 ha-mm canal water was applied at each irrigation. Nitrogen (16 kg N/ha) and phosphorus (40 kg P_2O_5/ha) were applied through diammonium phosphate (DAP), while sulphur was applied through gypsum as per treatments as basal application. The total rainfall was 70.8 and 37.3 mm with 4 and 3 rainy days during 2 respective crop seasons; however, in the first year most of rainfall was received at the end of crop season, while in second year during mid of the crop season.

RESULTS AND DISCUSSION

Effect of irrigation

The pooled mean of 2 years revealed that application of 2 irrigations at pre-flowering and pod-development stages significantly increased plant height and dry matter over 1 irrigation at pre-flowering stage and no post-sowing irrigation though 1 irrigation at pre-flowering was significantly better than the control. Number as well as dry weight of root nodules/plant decreased with increasing levels of irrigation but the reduction was non-significant (Table 1). Number of pods/plant, test weight, seed yield/ plant and seed and straw yields increased significantly up to 2 irrigations; however, the harvest and appreciation index increased significantly only up to 1 irrigation (Tables 1, 2). Two irrigations gave 16.4 and 7.4% more seed yield over no irrigation and 1 irrigation respectively. Maximum consumptive use of water and S uptake were recorded with 2 irrigations; however, maximum water-use efficiency (WUE) was obtained in no irrigation treatment. The availability of moisture at these 2 critical stages of moisture stress in chickpea obviously contributed to increase in growth attributes (Naresh *et al.,* 1985). The increased dry-matter production in turn might have resulted in greater synthesis of photosynthates contributing to increase in yield attributes. The better plant growth and improved yield attributes finally led to higher seed and straw yields, as also reported by Reddy and Ahlawat (1998) and Kaushik and Chaubey (1999).

Effect of sulphur

Date (Tables 1, 2) revealed that growth (dry matter, number and dry weight of root nodules/plant) and yield attributes (pods/plant, test weight, seed yield/plant) increased significantly with increasing levels of sulphur up to 40 kg/ha; however, plant height increased significantly only up to 20 kg/ha. The increase over the control at 20 and 40 kg/ha of S application was 18.2 and 28.0% for dry matter, 15.7 and 27.3% for number of root nodules and 15.1 and 25.6% for dry weight of root nodules. Increasing levels of sulphur significantly increased seed yield, harvest and application index and S uptake by seed and straw up to 40 kg S/ha, while straw yield increased significantly only up to 20 kg S/ha. The increase over the control was 9.3 and 15.8% in seed yield and 5.7 and 10.5% in straw yield with sulphur applied at 20 and 40 kg/ha respectively. There was no marked increase in consumptive use of water, but the WUE increased with S application. The improvement in crop growth, nodulation and yield attributes with sulphur application could be ascribed to its pivotal role in regulating the metabolic and enzymatic processes including photosynthesis, respiration and legume-*Rhizobium* symbiotic nitrogen fixation which reflected in increased yields (Rao *et al.,* 2001).

Effect of seed inoculation

Combined seed inoculation with *Rhizobium* + PSB significantly increased plant height, dry matter, number and dry weight of root nodules/plant, pods/plant, seed yield/

Table 1. Growth, nodulation and yield attributes of chickpea as affected by irrigation, sulphur and seed inoculation levels (pooled mean of 2 years)

Treatment	Plant height (cm) at harvest	Dry matter (g/plant) at harvest	Root nodules/plant at 120 DAS	Dry weight of root nodules (mg/plant) at 120 DAS	Pods/ plant	Test weight (g)	Seed yield (g/plant)
Irrigation							
I_0	47.78	12.91	9.88	54.69	26.95	125.93	3.81
I_1	54.04	15.47	9.61	52.71	32.07	130.37	4.50
I_2	59.59	17.02	9.49	52.15	34.72	135.28	4.85
CD (P=0.05)	1.77	0.42	NS	NS	1.75	3.04	0.18
Sulphur							
S_0	50.61	13.11	8.45	46.83	27.70	125.32	3.88
S_1	54.45	15.50	9.78	53.91	31.70	130.50	4.47
S_2	56.35	16.78	10.76	58.82	34.34	135.75	4.80
CD (P=0.05)	1.77	0.42	0.50	2.74	1.75	0.18	
Seed inoculation							
B_0	53.07	13.76	8.35	45.26	29.14	129.23	3.98
B_1	53.73	15.26	9.67	52.13	31.25	130.49	4.40
B_2	53.44	14.98	9.42	50.63	30.90	130.21	4.35
B_3	54.96	16.52	11.21	64.72	33.69	132.18	4.81
CD (P=0.05)	1.39	0.36	0.51	2.60	0.69	1.10	0.17

Details of treatments are given under Materials and Methods

Table 2. Yield harvest index, appreciation index, water-use and S uptake of chickpea as affected by irrigation, sulphur and seed inoculation levels (pooled mean of 2 years)

Treatment	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Appreciation index (%)	Consumptive use of water (mm)	Water-use efficiency (kg/ha-mm)	S uptake (kg/ha)	
							Seed	Straw
Irrigation								
I_0	1,427	3,495	28.95	40.77	184.05	7.75	5.82	6.92
I_1	1,547	3,734	29.26	41.39	211.90	7.30	6.10	7.08
I_2	1,661	3,975	29.44	41.75	236.72	7.01	6.38	7.24
CD (P=0.05)	80	175	0.25	0.50			NS	NS
Sulphur								
S_0	1,426	3,543	28.68	40.22	205.58	6.93	5.32	6.27
S_1	1,558	3,745	29.34	41.55	212.17	7.33	6.14	7.15
S_2	1,651	3,916	29.64	42.15	214.92	7.68	6.83	7.82
CD (P=0.05)	80	175	0.25	0.50			0.61	0.41
Seed inoculation								
B_0	1,497	3,673	28.91	40.69	208.13	7.19	5.78	6.84
B_1	1,539	3,724	29.20	41.27	210.79	7.30	6.09	7.08
B_2	1,533	3,713	29.19	41.25	210.29	7.29	6.02	7.06
B_3	1,611	3,827	29.27	42.02	214.36	7.51	6.50	7.34
CD (P=0.05)	23	56	0.24	0.48			0.22	0.19

Details of treatments are given under Materials and Methods
Application index is ratio of economic yield (seed yield) and straw yield

plant, seed and straw yields, harvest and appreciation index and S uptake by seed and straw over single inoculation with PSB or *Rhizobium* and control; however, single inoculation with either PSB and *Rhizobium* being at par, were significantly superior to the control (Tables 1, 2). In case of test weight, combined inoculation was significant over rest of the seed inoculation levels which were at par among themselves. Combined seed inoculation recorded maximum WUE; however, consumptive use of water could not increase markedly.

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